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Site-Specific Tillage Management and Crop Yield Response

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Introduction

Tillage decision is only one issue farmers have to make during fall. There are many factors that need to be considered in selecting a tillage system for any given field or region within the state. Those factors are soil conditions, which can include, soil slope, soil drainage, top soil depth or the A-horizon depth. Other factors need to be considered, which are equally important. They are management factors, such as, residue cover, type of residue (corn or soybean), soil moisture condition at the time of making the decision, timing of tillage operation, fertilizer management in conjunction with tillage operation, type of residue management equipment, planting and harvesting equipment, compliance with conservation plans, and above all, is the economic return and benefits of selecting any tillage system.

The variability in soil conditions will be a key factor in selecting a tillage system that will influence crop response and ultimately yield expectations. However, crop response to different tillage systems has been demonstrated to be different than the same tillage system in a different part of the state or different regions elsewhere. Different tillage systems affect soil temperature, soil moisture conditions, soil compaction, soil productivity, and nitrogen movement and N availability differently. These effects will be indicated in crop response to different tillage systems, where soil temperature plays a significant role in early seed germination, mineralization of the organic matter, nutrient and residue incorporation, and weed and pest control.

The site specific of tillage selection can help significantly in reducing cost input and reduce the negative impact on water, air, and soil quality. Conservation tillage systems continue to be a very important component of a crop production system in terms of economic return and environmental benefits. However, the challenges in managing such systems, and namely no-tillage, are related to proper management practices, such as the availability of drainage in poorly drained soils, use of residue management attachments, seeding depth, and fertilizer management. Also, the timing of conducting field operations, whether N application, manure injection, etc. needs to be done when the soil moisture condition is below field capacity to avoid serious soil compaction problems.

Soil moisture and soil temperature conditions in the seedbed zone (top 6 inches) can promote or delay seed germination and plant emergence (Kaspar et al., 1990; Schneider and Gupta, 1985). Therefore, healthy plant growth and development require soil conditions that have adequate soil moisture and minimal root penetration resistance (Phillips and Kirkham, 1962). Soil temperature can be affected by surface residue cover, causing cooler surface soil temperature and slower soil drying in the spring (Fortin, 1993; Kaspar et al., 1990) in spite of reducing soil erosion and surface runoff (Cruse et al., 2001). Removal of residue from the row can reduce in-row soil moisture content in the seedbed, while conserving interrow soil moisture. Unlike soil moisture, soil temperature has an inverse relationship with the amount of residue cover.

Soil porosity, structure, and strength are impacted by excessive soil compaction and are often differentiated by penetration resistance (Croissant et al., 1991; Voorhees, 1983). Penetration resistance is a common measure of soil strength, where increased penetration resistance restricts root growth (Singh et al., 1992; Taylor and Ratliff, 1969; Voorhees et al., 1975). A reduction of crop growth and yield is attributed to penetration resistance (Croissant et al., 1991; Phillips and Kirkham, 1962). Quantifying the effects of tillage systems on soil moisture, soil temperature, and compaction can help explain some of the differences in plant growth and development in different tillage systems.

Tillage systems have a significant effect on N dynamics by affecting N pools in the soil system. Soil disturbance during the tillage process and the incorporation of surface residue increases soil aeration, which can increase the rate of residue decomposition (McCarthy et al., 1995). This process impacts soil organic N mineralization whereby readily available N for plant use is increased (Dinnes et al., 2002). The type of tillage system can influence the amount of N available for loss in the soil profile. Deep accumulation of NO_3-N in the soil profile represents a potential for NO_3-N leaching into shallow water tables (Keeney and Follett, 1991).

Another alternative to the no-tillage system is strip-tillage or zone-tillage, which has the potential of creating ideal planting conditions by combining the benefits of conventional tillage and no-tillage by disturbing the row and leaving the interrow with complete residue cover (Vyn and Raimbault, 1993). This unique characteristic of leaving the interrow residue in place, while disturbing a narrow zone 6 to 12 inches in width by 6 to 12 inches in depth has attracted the attention of many producers during the last decade who have experienced difficulties with no-tillage. Strip-tillage also offers an opportunity to apply nutrients and prepare a seedbed in one tillage operation. This tillage system may provide a potential solution to some of the nutrient and water quality problems associated with conventional tillage and to a certain extent with no-tillage, namely, nutrient use efficiency, surface water runoff, and deep NO_3-N leaching.

Results and Discussion

Yield response

- Corn yield response to tillage is site or area specific.
- In some areas second year corn yield was higher than that of corn after soybean within each tillage system
- Tillage system had no effect on soybean yield across all areas
- Moisture shortage caused significant yield reduction in corn and soybean regardless of tillage system

Tillage Effect on Soil Temperature

- Generally, soil temperature was not affected by any particular tillage system in the early hours of the day for either location. However, when maximum air temperature was reached, strip-tillage and chisel plow tillage systems were at a higher soil temperature than no-tillage. (Fig. 1)

Tillage Effect on Soil Moisture

- At the tasseling and pre-harvest growth stages the soil moisture content under all tillage systems was not significantly different at any depth. (Fig. 2)

- Soil moisture under NT was consistently lower than under the ST and CP at the post emergence, tasseling, and pre-harvest periods, whereas ST and CP did not result in any significant soil moisture differences. (Fig. 3)

Tillage Effect on Soil Penetration Resistance

- During the May and June periods at the 0- to 4-inch soil depth, ST penetration resistance was similar to that of NT, and both had a significantly greater penetration resistance than CP
- During July, the penetration resistance tended to generally increase with depth, and the penetration resistance of ST and CP was lower than that of NT (Fig. 4)

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Table 1. Corn and soybean yields under a corn-soybean rotation at the ISU Armstrong Research Farm.

	Corn (C-s)		Soybean (c-S)	
	2002[b]	2004	2003[b]	2005
	------ bushels / acre ------			
No-Tillage	92.2	214.9	39.8	60.8
Strip-Tillage	91.4	218.9	38.3	55.6
Deep Rip	91.0	235.1	39.7	56.7
Chisel Plow	88.3	232.0	35.7	56.5
Moldboard Plow	107.4	226.3	33.8	55.6
$LSD_{(0.05)}$ [a]	20.8	14.2	3.5	4.6
5-Tillage Average	94.1	225.4	37.5	57.1

[a] Least significant differences ($LSD_{(0.05)}$) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

[b] Weather conditions in 2002 and 2003 were 12.25 and 10.51 inches of precipitation below normal.

Table 2. Corn and soybean yields under a corn-corn-soybean rotation the ISU Armstrong Research Farm.

	Corn (C-c-s)	Corn (c-C-s)	Soybean (c-c-S)	
	2003[b]	2004	2002[b]	2005
	----------- bushels / acre -----------			
No-Tillage	151.8	221.0	36.7	60.9
Strip-Tillage	142.7	224.3	35.7	56.8
Deep Rip	146.3	231.8	35.5	55.4
Chisel Plow	136.8	228.7	36.7	59.1
Moldboard Plow	133.8	238.2	35.7	56.3
$LSD_{(0.05)}$ [a]	17.5	11.5	6.4	4.2
5-Tillage Average	142.3	228.8	36.1	57.7

[a] Least significant differences ($LSD_{(0.05)}$) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

[b] Weather conditions in 2002 and 2003 were 12.25 and 10.51 inches of precipitation below normal.

Table 3. Corn and soybean yields under a corn-soybean rotation at the ISU Crawfordsville Research Farm.

	Corn (C/s)			Soybean (c/S)		
	2003	2004	2005	2003	2004	2005
	----------- bushels / acre -----------					
No-Tillage	212.8	180.0	171.3	38.7	55.1	77.2
Strip-Tillage	205.9	190.7	168.3	39.5	55.9	69.8
Deep Rip	209.7	200.2	171.0	42.2	57.7	70.2
Chisel Plow	211.6	207.9	177.4	40.6	55.7	69.5
Moldboard Plow	202.7	214.0	179.2	41.7	58.3	69.8
$LSD_{(0.05)}$ [a]	16.1	22.8	13.9	3.2	3.3	5.4
5-Tillage Average	208.5	169.3	173.4	40.5	56.9	69.8

[a] Least significant differences ($LSD_{(0.05)}$) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

Table 4. Corn and soybean yields under a corn-corn-soybean rotation at the ISU Crawfordsville Research Farm

	Corn (C-c-s)	Corn (c-C-s)	Soybean (c-c-S)
	2005	2003	2004
	----------- bushels / acre -----------		
No-Tillage	165.5	129.8	57.6
Strip-Tillage	158.8	149.0	59.7
Deep Rip	163.9	146.1	60.0
Chisel Plow	163.3	157.7	59.8
Moldboard Plow	164.3	149.4	58.8
$LSD_{(0.05)}$ [a]	8.6	25.6	2.6
5-Tillage Average	163.2	146.4	59.2

[a] Least significant differences ($LSD_{(0.05)}$) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

Table 5. Corn and soybean yields under a corn-soybean rotation at the ISU Kanawha Research Farm.

	Corn (C/s)			Soybean (c/S)		
	2003	2004	2005	2003	2004	2005
			----------- bushels / acre -----------			
No-Tillage	187.7	172.4	136.6	38.2	56.5	54.6
Strip-Tillage	191.7	181.1	146.0	38.0	57.8	54.1
Deep Rip	190.7	188.8	181.3	39.4	57.1	53.1
Chisel Plow	198.3	192.2	189.2	39.9	56.8	52.2
Moldboard Plow	196.7	191.2	188.5	40.7	57.8	53.5
$LSD_{(0.05)}$ [a]	32.2	11.2	24.7	3.7	4.4	3.5
5-Tillage Average	193.0	185.1	168.3	39.2	57.2	53.5

[a] Least significant differences ($LSD_{(0.05)}$) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

Table 6. Corn and soybean yields under a corn-corn-soybean rotation at Kanawha Research Farm.

	Corn (C-c-s)	Corn (c-C-s)	Soybean (c-c-S)
	2005	2003	2004
		----------- bushels / acre -----------	
No-Tillage	174.1	214.0	37.4
Strip-Tillage	192.3	220.1	34.9
Deep Rip	188.5	223.2	38.9
Chisel Plow	198.6	218.3	37.5
Moldboard Plow	200.9	232.0	39.3
$LSD_{(0.05)}$ [a]	14.5	9.7	2.4
5-Tillage Average	190.9	221.5	31.7

[a] Least significant differences ($LSD_{(0.05)}$) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

Table 7. Corn and soybean yields under a corn-soybean rotation at the ISU Western Research Farm.

	Corn (C-s)	Soybean (c-S)	
	2004	2003 [b]	2005
		---- bushels / acre ----	
No-Tillage	166.4	31.2	52.1
Strip-Tillage	167.7	28.6	51.0
Deep Rip	180.5	27.4	45.7
Chisel Plow	184.3	28.3	46.5
Moldboard Plow	178.7	26.8	45.2
$LSD_{(0.05)}$ [a]	7.5	2.4	3.3
5-Tillage Average	175.5	28.4	48.1

[a] Least significant differences ($LSD_{(0.05)}$) are based on a Fisher test. [b] Weather conditions in 2003 were 10.51 inches of precipitation below normal.

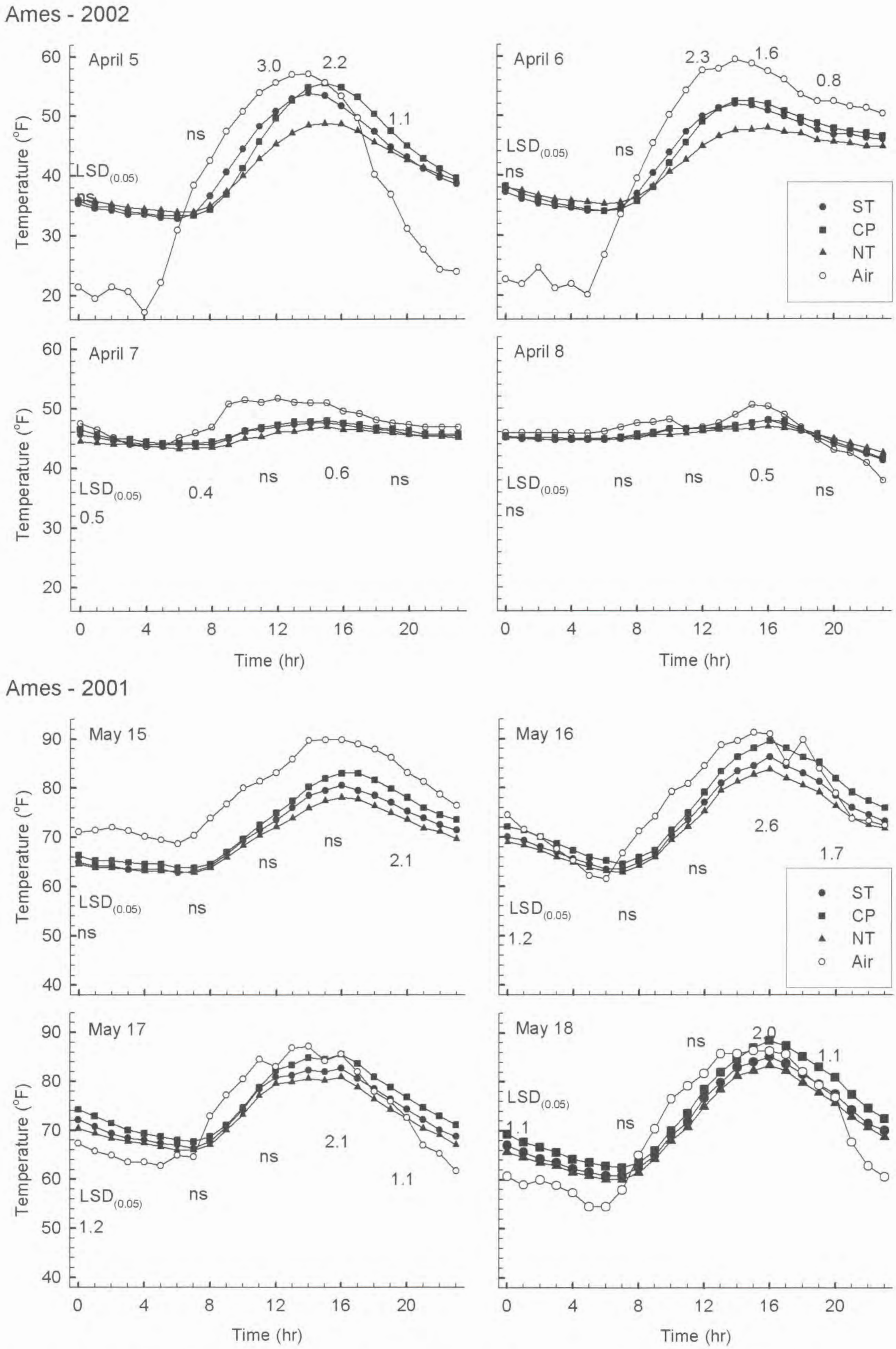

Figure 1. Hourly soil temperature at the 5-cm soil depth at the Ames site in 2001 and 2002. The least significant differences of the 0, 8, 12, 16, and 20 h are according to Fisher's $LSD_{(0.05)}$ test.

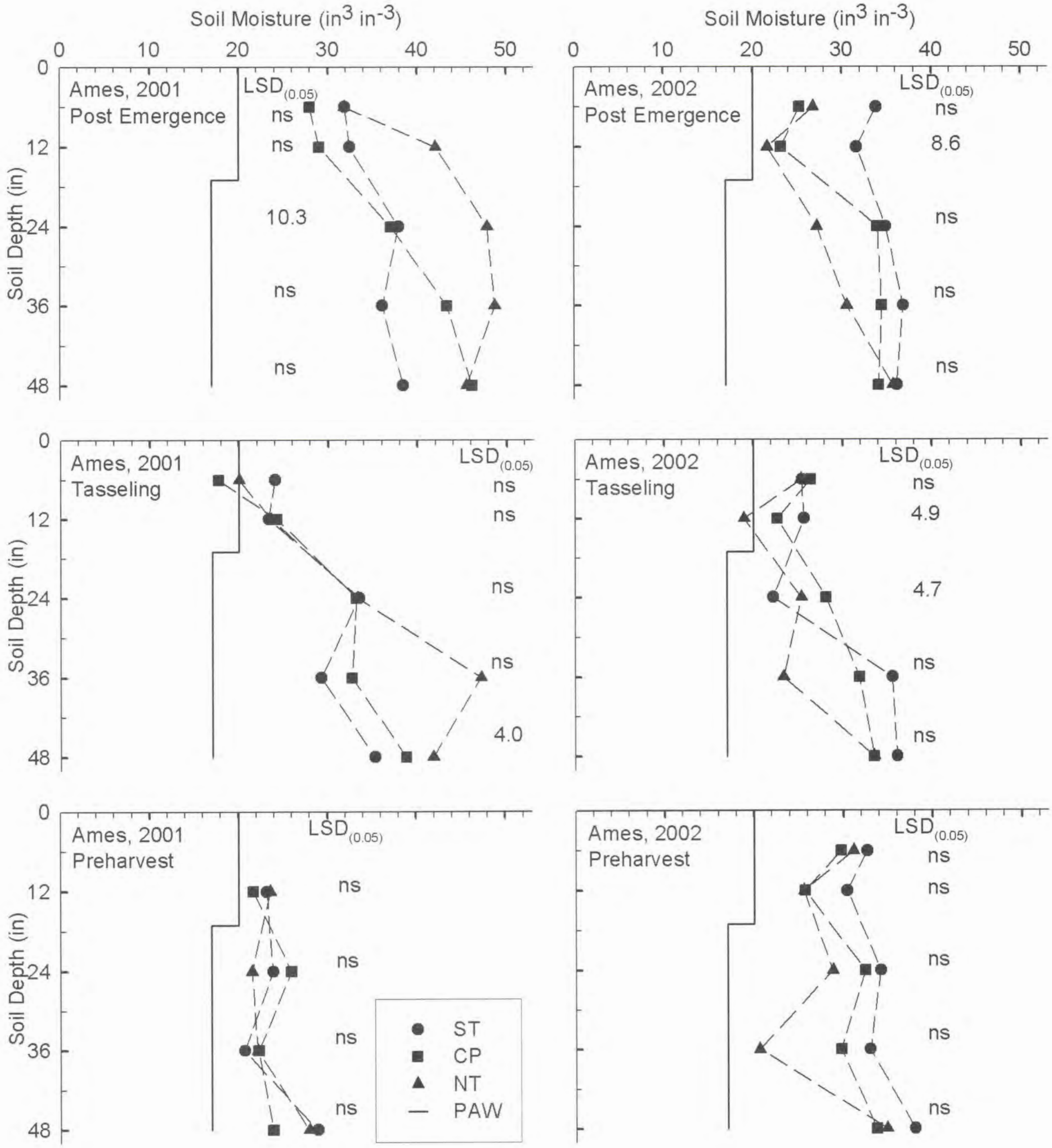

Figure 2. Soil moisture profile for the Ames site in 2001 and 2002. Post emergence, tasseling, and preharvest measurements were taken on 8 June, 10 July, and 28 August 2001 and on 28 May, 9 July, and 19 August 2002, respectively. The least significant differences are according to Fisher's $LSD_{(0.05)}$ test.

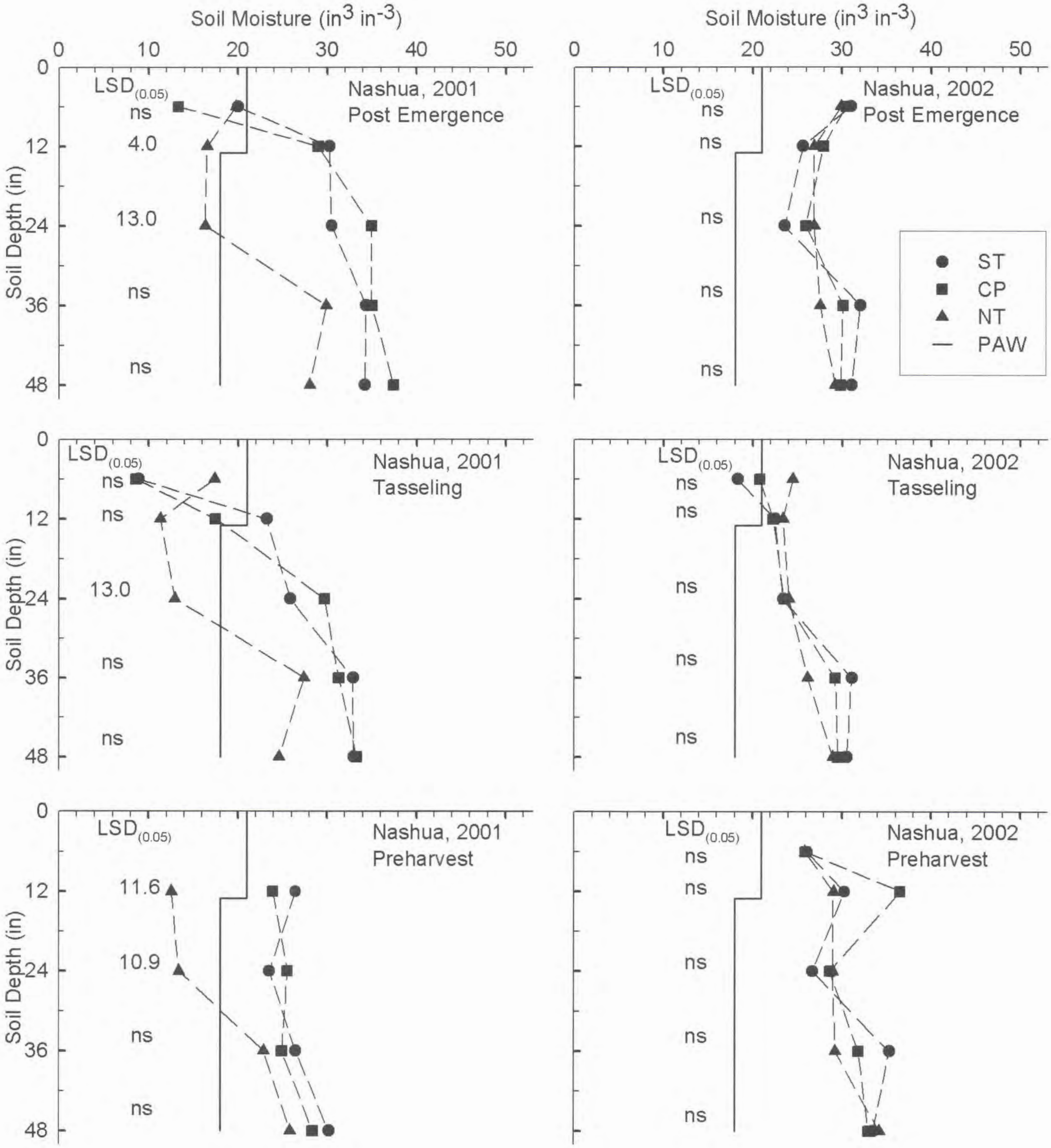

Figure 3. Soil moisture profile for the Nashua site in 2001 and 2002. Post emergence, tasseling, and preharvest measurements were taken on 28 June, 12 July, and 22 August 2001 and on 30 May, 16 July, and 20 August 2002, respectively. The least significant differences are according to Fisher's $LSD_{(0.05)}$ test.

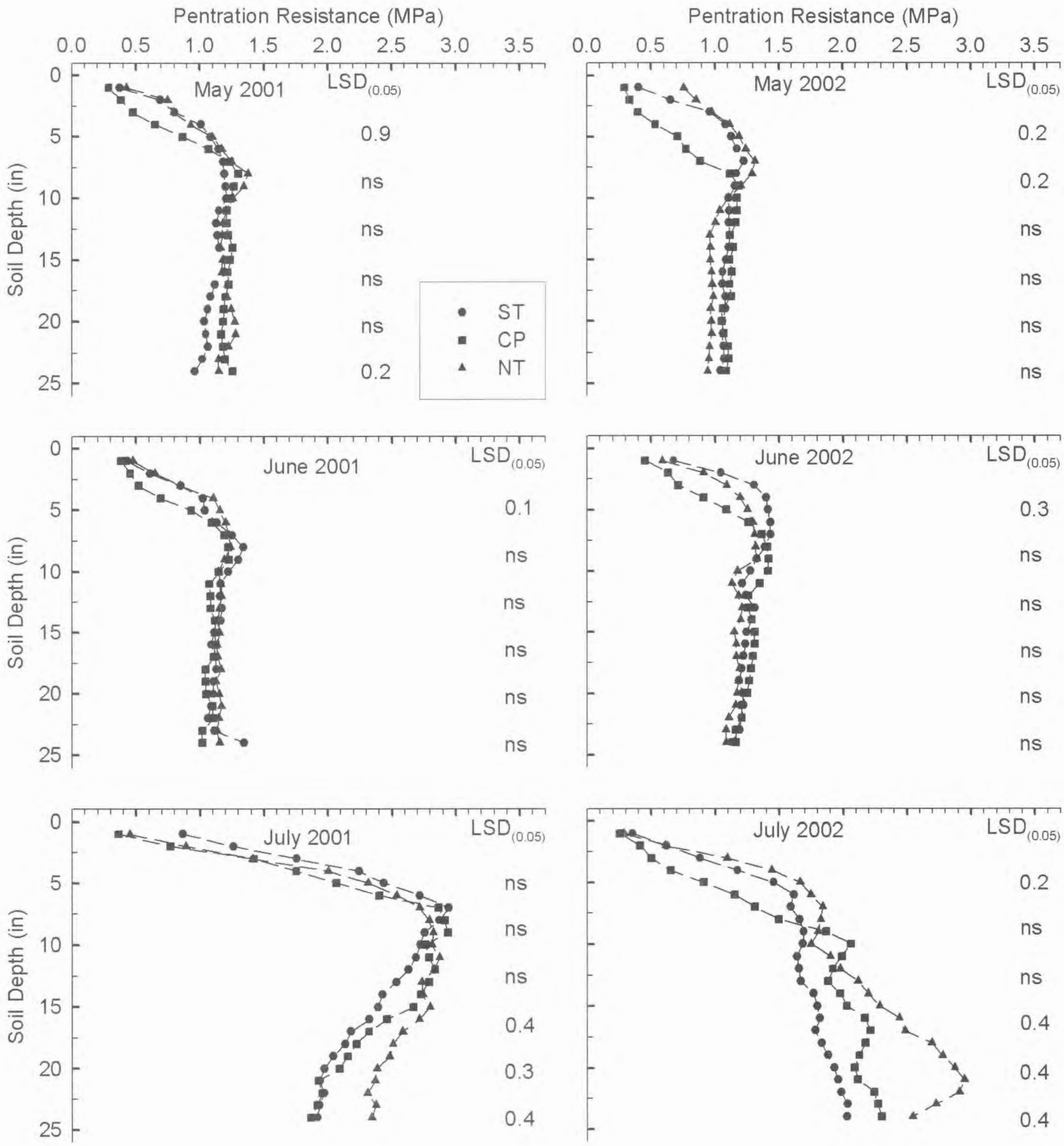

Figure 4. Penetration resistance for the soil profile at the Ames site in 2001 and 2002. The actual recording periods were 15 May, 12 June, and 10 July 2001 and 14 May, 17 June, and 9 July 2002, respectively. The least significant differences are according to Fisher's $LSD_{(0.05)}$ test.

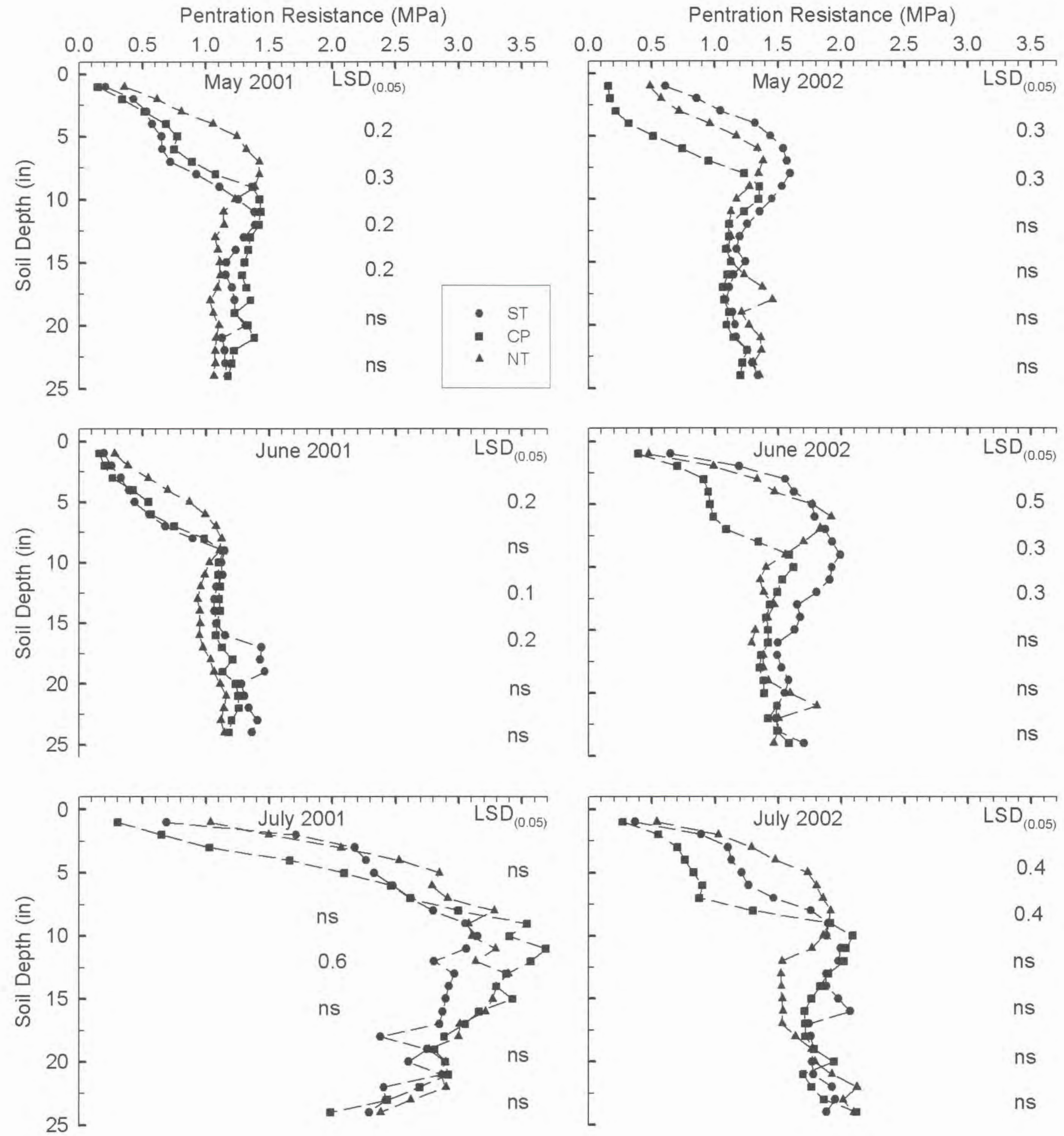

Figure 5. Penetration resistance for the soil profile at the Nashua site in 2001 and 2002. The actual recording periods were 18 May, 15 June, and 12 July of 2001 and 13 May, 18 June, 16 July of 2002, respectively. The least significant differences are according to Fisher's $LSD_{(0.05)}$ test.